STRESS TESTING
CLIMATE FINANCIAL RISK

Ron Dembo
December12, 2019

1

CLIMATE RISK IS NOT PRICED INTO THE MARKET

… AND ENTIRE ECONOMIES WILL BE AFFECTED

ALSO, CLIMATE SCENARIOS ARE AD HOC AND INCONSISTENT.

Ad hoc scenario generation

Impossible to compare across markets

Current comparisons are apples to oranges

EXECUTIVE SUMMARY

A key challenge has been the creation of meaningful multi-factor scenarios for stress testing climate change impact.

We have been able to develop an evidence-based algorithm for generating, standardized sets of forward-looking scenarios.

This makes it possible to generate scenario sets that apply to transition and physical risks for multiple companies covering multiple sectors in the economy.

Our method guarantees that the best and worst-case scenarios will be in the set ("a spanning set").

THE PRESENTATION

1. The pressures that will influence climate change financial risk.

2. The Tipping Points that bring us closer to forcing action on climate risk.

3. A solution to the measurement of climate related financial risk.

4. What needs to be developed in order to get there.

5. A proposal for how to regulate climate financial risk

MARKET
PRESSURES

Stranded Assets

"Asset stranding results when assets have suffered from unanticipated or premature write-downs, devaluations or conversion to liabilities"

Caldecott et.al.

7

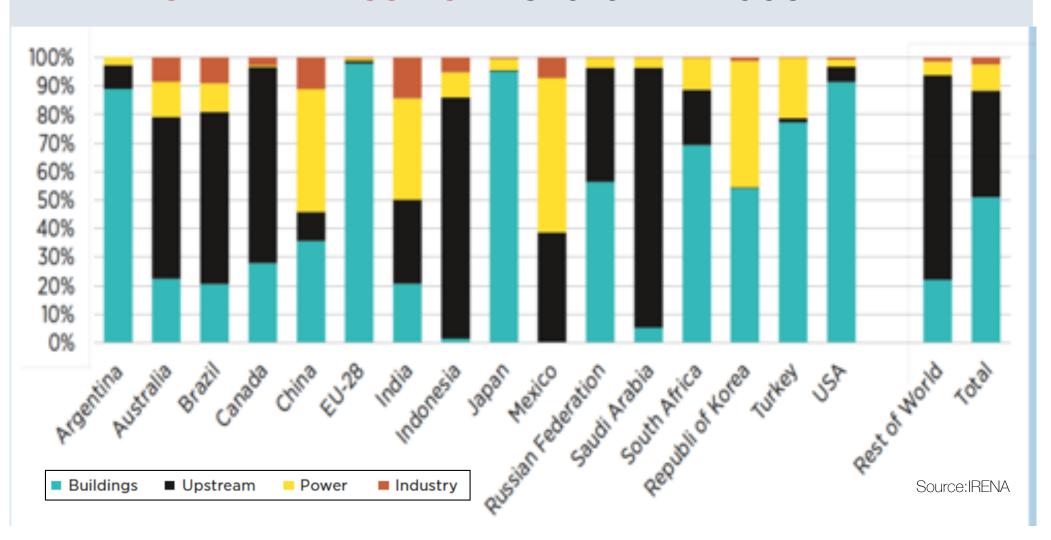# STRANDED ASSETS - CAUSES

Regulatory stranding   –   policy

Economic stranding   s–   consumer preference

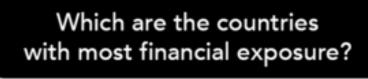Physical stranding   –   due to distance / flood / drought

The fear is that one or more of these will happen **SUDDENLY.**

STRANDED ASSETS BY SECTOR AND COUNTRY

Source:IRENA

STRANDED OIL ASSETS AND CANADA?

Which are the countries with most financial exposure?

Canada
$220bln

Russia
$147bln

US
$412bln

China
$179bln

Australia
$103bln

SOVEREIGN FUNDS

Norway's largest pension fund pulls out of Alberta oilsands, removes four Calgary-based companies

Mark Villani
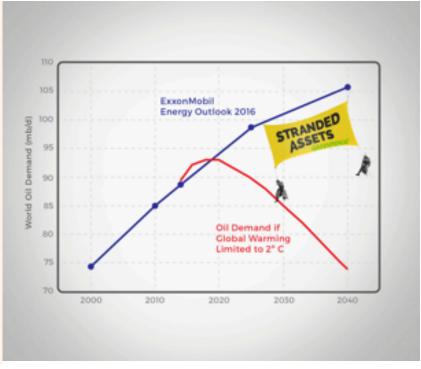Published Wednesday, October 9, 2019 7:34AM

RATING AGENCIES

ESG investing + Add to myFT

Credit rating agencies focus on rising green risks

Moody's warning on ExxonMobil marks watershed for debt markets

ExxonMobil could lose its triple-A rating © Reuters

ExxonMobil Energy Outlook 2016

STRANDED ASSETS GREENPEACE

Oil Demand if Global Warming Limited to 2° C

France to stress test banks, insurers' climate risks next year

NOV.29,2019

Facebook   Twitter   More
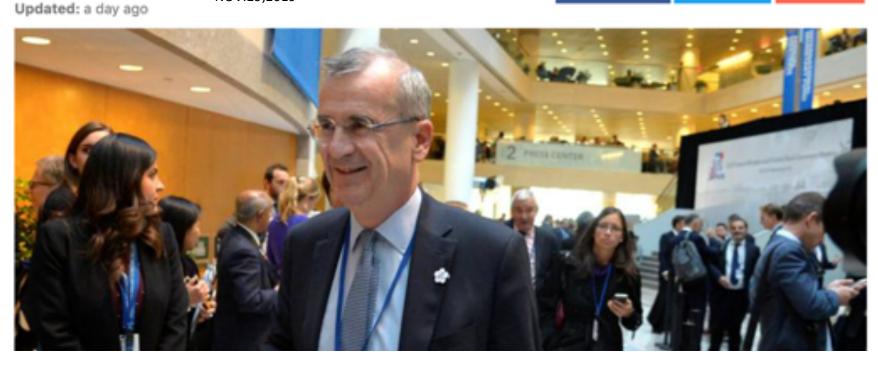
IMPENDING REGULATIONS

…climate risk "absolutely has to be at the front and center in our work."

– Kristalina Georgieva,
Managing Director, IMF

BOE to stress test its financial system against 'climate pathways'

Mark Carney,
Governor, BOE

MANDATING GREEN INVESTMENTS

European Central Bank   + Add to myFT

Christine Lagarde wants key role for climate change in ECB review

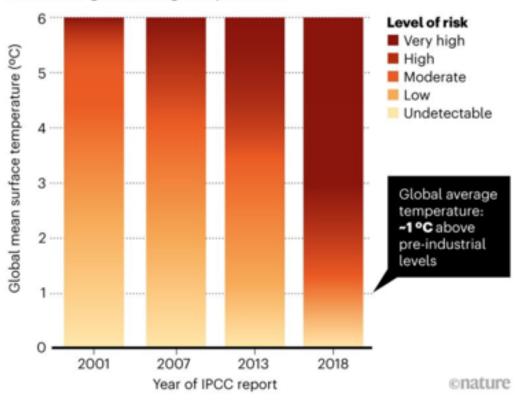Initiative likely to set up clash with German central banker Jens Weidmann

ECB president Christine Lagarde puts her signature on a €20 banknote © Armando Babani/EPA/Shutterstock

THE
RISKS

ABRUPT AND IRREVERSIBLE CHANGES

TOO CLOSE FOR COMFORT
Abrupt and irreversible changes in the climate system have become a higher risk at lower global average temperatures.
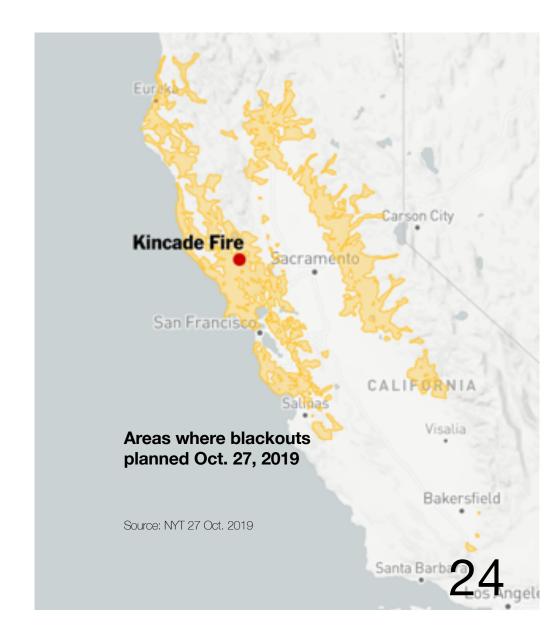
Source: IPCC

ONE "Maria" TO **SUDDENLY** DESTROY A TERRITORY's ECONOMY

Puerto Rico, 2019

18

ONE FLOOD TO DESTROY A COMMUNITY.

Winnipeg, Manitoba, 2014

19

ONE CROP FAILURE TO DESTROY A SUPPLY CHAIN.

Russia, 2010
General Mills

20

ONE
DROUGHT
TO FUEL A
REFUGEE
CRISIS.

Guatemala,
2019

21

ONE SPARK, HEAT, DROUGHT AND STRONG WINDS **SUDDENLY** CRIPPLED A UTILITY.

PG&E Bankruptcy, 2019

22

PG&E

Nov. 2018	Jan. 2019	Value Destroyed
$25B	$3B	↓ 87%

23

A SIGNIFICANT **SUDDEN** IMPACT ON THE CALIFORNIAN ECONOMY

Multiple Risk Factors:
Drought
Temperature
High wind

Kincade Fire

Areas where blackouts planned Oct. 27, 2019

Source: NYT 27 Oct. 2019

24

SOCIAL RISK

Bulletin of the Atomic Scientists

Doomsday Clock | Nuclear Risk | Climate Change | Disruptive Technologies | Support

IT IS 2 MINUTES T

imate Change > How climate-related tipping points can trigger mass migration and social chaos

How climate-related tipping points can trigger mass migration and social chaos

By Perry World House, November 8, 2019

Perry World House

Perry World House is the University of Pennsylvania's hub for global engagement. It contributes a regular column to the *Bulletin* on the implications of emerging

FOOD RISK

Science Advances

Escaping the perfect storm of simultaneous climate change impacts on agriculture and marine fisheries

Lauric Thiault[1,2,*], Camilo Mora[3], Joshua E. Cinner[4], William W. L. Cheung[5], Nicholas A. J. Graham[6], Fraser A. Januch...
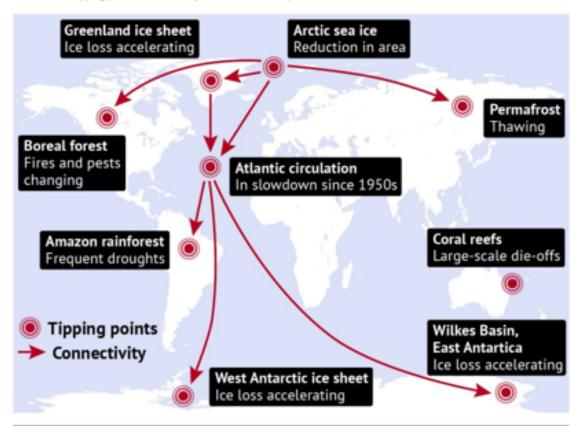
90% of the world's population—most of whom live in the most sensitive and least developed countries—are projected to be exposed to losses of food production in both sectors, while less than 3% would live in regions experiencing simultaneous productivity gains by 2100.

THE
TIPPING
POINTS

TIPPING POINTS

Active global warming tipping points

Evidence that tipping points are under way has mounted in the past decade.

Greenland ice sheet
Ice loss accelerating

Arctic sea ice
Reduction in area

Permafrost
Thawing

Boreal forest
Fires and pests
changing

Atlantic circulation
In slowdown since 1950s

Amazon rainforest
Frequent droughts

Coral reefs
Large-scale die-offs

Tipping points
Connectivity

Wilkes Basin,
East Antartica
Ice loss accelerating

West Antarctic ice sheet
Ice loss accelerating

Source: Nature

CLIMATE PROCRASTINATION

2005 – To achieve UNEP goals
   need a CO_{2e} reduction of **2.0%/ year**

2010 – To achieve UNEP goals
   need a CO_{2e} reduction of **3.2%/ year**

2019 – To achieve UNEP goals
   need a CO_{2e} reduction of **7.6%/ year**

Ingar Andersen
Executive Director , UNEP

Where are we now?

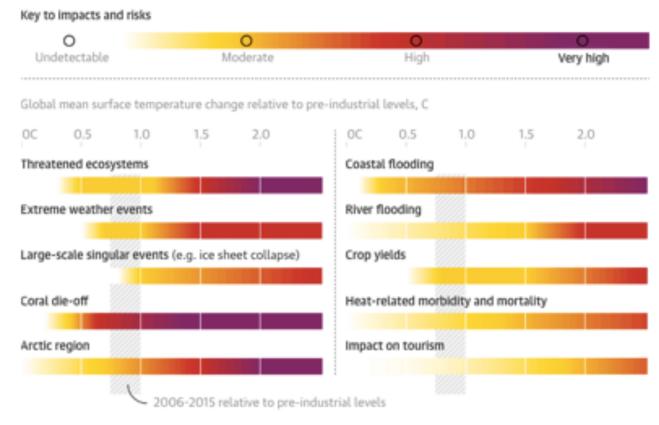Number of funds exiting from carbon intensive industries

"MINSKY"

?

Financial Pressure on Carbon intensive companies

THE
SOLUTION

IT STARTS BY IDENTIFYING THE RISK FACTORS
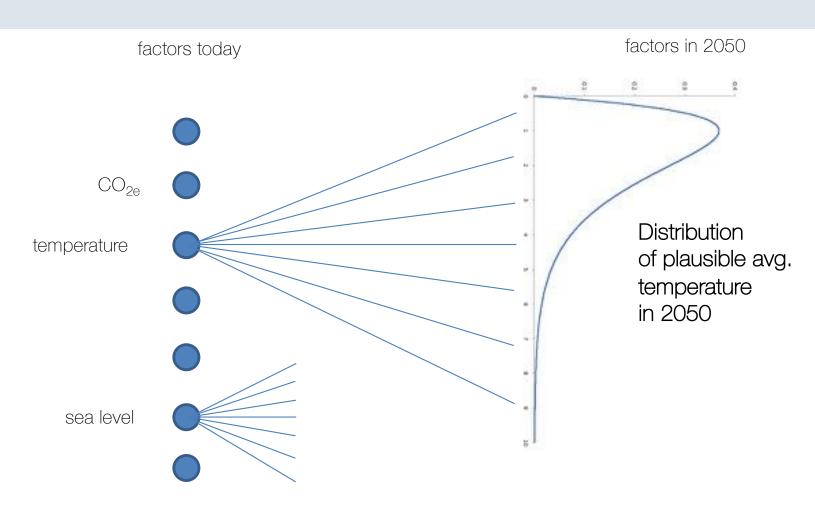
Rising temperatures, rising risks

Key to impacts and risks

Undetectable — Moderate — High — Very high

Global mean surface temperature change relative to pre-industrial levels, C

| 0C | 0.5 | 1.0 | 1.5 | 2.0 |

Threatened ecosystems

Extreme weather events

Large-scale singular events (e.g. ice sheet collapse)

Coral die-off

Arctic region

| 0C | 0.5 | 1.0 | 1.5 | 2.0 |

Coastal flooding

River flooding

Crop yields

Heat-related morbidity and mortality

Impact on tourism

2006-2015 relative to pre-industrial levels

Guardian graphic. Source: IPCC Special Report on Global Warming of 1.5C

MACRO FACTOR UNCERTAINTY

factors today

factors in 2050

CO_{2e}

temperature

sea level

Distribution
of plausible avg.
temperature
in 2050

For PILOT study
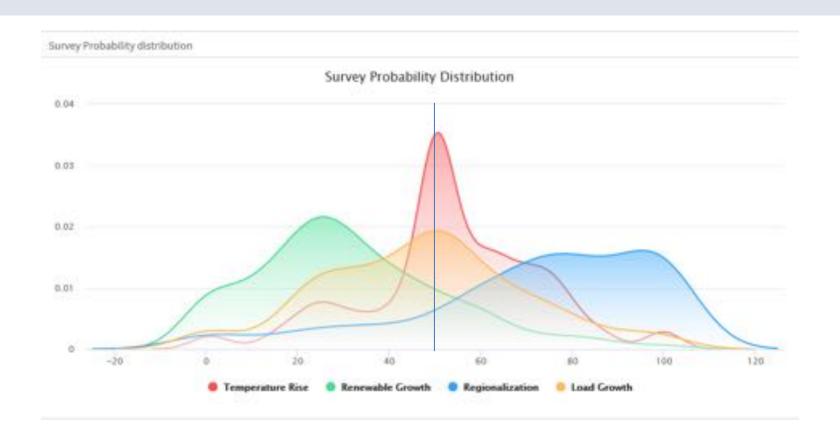
Factor 1:   Higher or lower temperature relative to expected

Factor 2:   Higher or lower relative cost of renewables

Factor 3:   More or less regional grid than expected

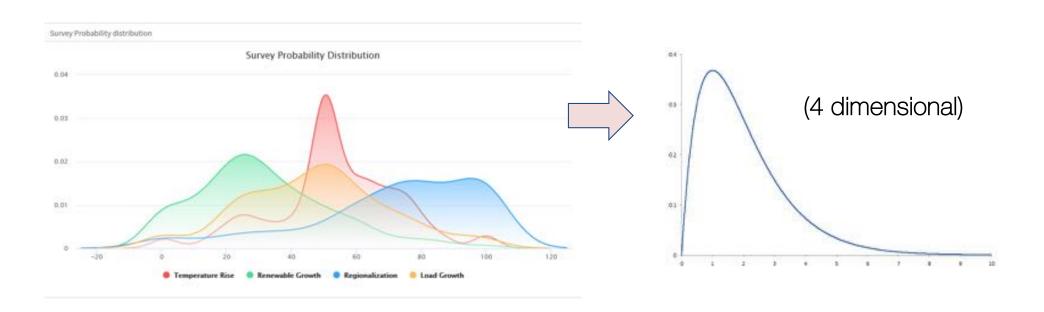Factor 4:   More or less load than expected

EXPERT FORWARD SENTIMENT

Survey Probability distribution

Survey Probability Distribution

● Temperature Rise ● Renewable Growth ● Regionalization ● Load Growth

DERIVING THE MULTIFACTOR DISTRIBUTION

Given $D_1(f_1); D_2(f_2); D_3(f_3); D_4(f_4)$ derive $D(f_1, f_2, f_3, f_4)$

(4 dimensional)
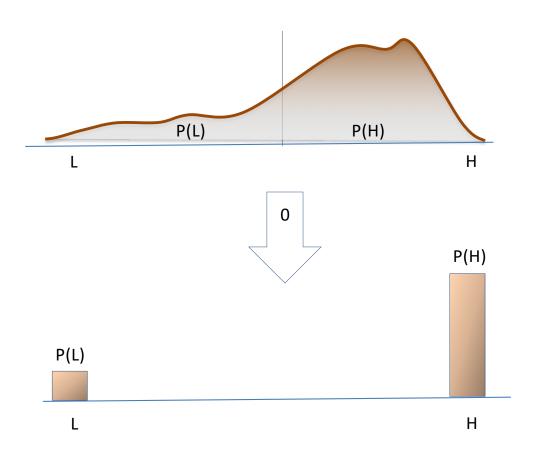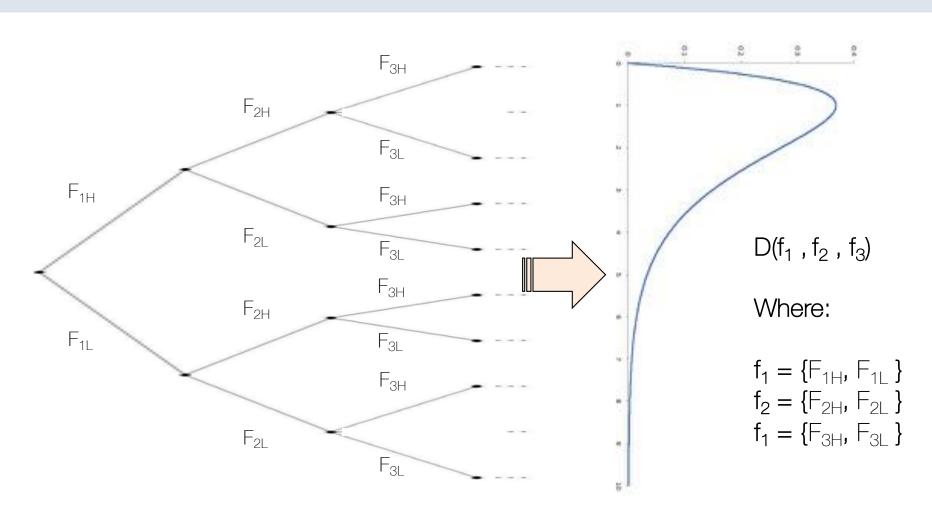
A "BASEL 5" FOR CLIMATE RISK!

1. Require firms to maintain data on the risk factors that affect their business;

2. Require the ability to properly generate forward-looking distributions for appropriate future horizons;

3. Require firms to maintain adequate modelling capabilities for converting the single factor distributions, to distributions of multiple risk factors;

4. Pass these tests or face higher capital charges.

A BINARY APPROXIMATION FOR SCENARIO GENERATION

F_{3H}

F_{2H}

F_{3L}

F_{3H}

F_{1H}

F_{2L}

F_{3L}

F_{3H}

F_{2H}

F_{1L}

F_{3L}

F_{3H}

F_{2L}

F_{3L}

$D(f_1 , f_2 , f_3)$

Where:

$f_1 = \{F_{1H}, F_{1L}\}$
$f_2 = \{F_{2H}, F_{2L}\}$
$f_1 = \{F_{3H}, F_{3L}\}$

CLIMATE CHANGE IS A FAT-TAILED PROBLEM

FIGURE SOURCE: IPCC AR4 WG1 report

FACTOR INTERDEPENDENCY
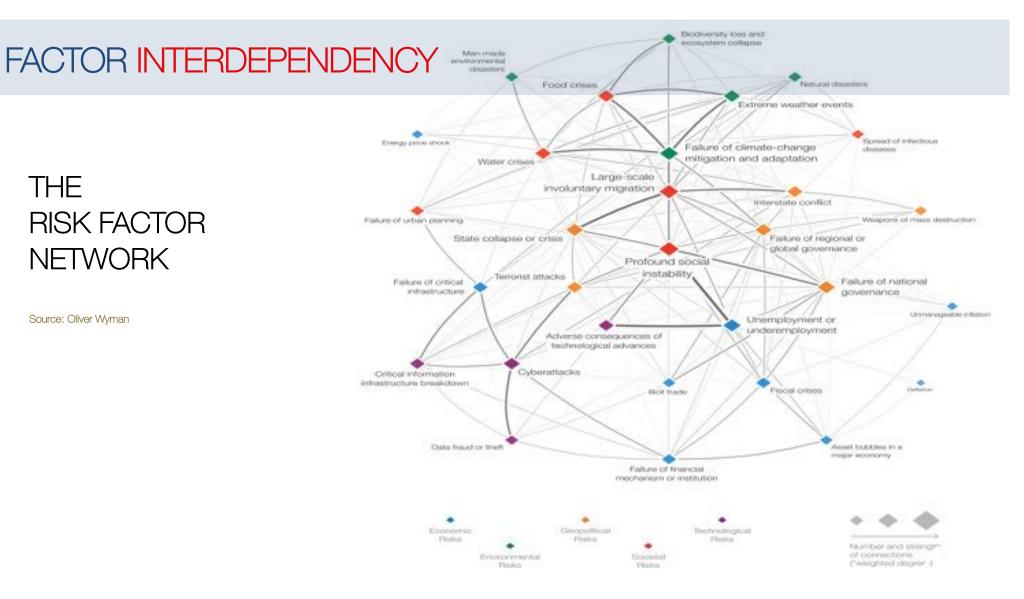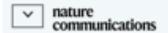
THE
RISK FACTOR
NETWORK

Source: Oliver Wyman

…BUT WHERE DO WE FIND DATA FOR GENERATING THE FACTOR DISTRIBUTIONS?

TRUSTED SOURCE EXAMPLE
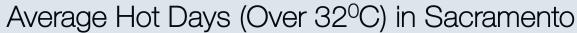
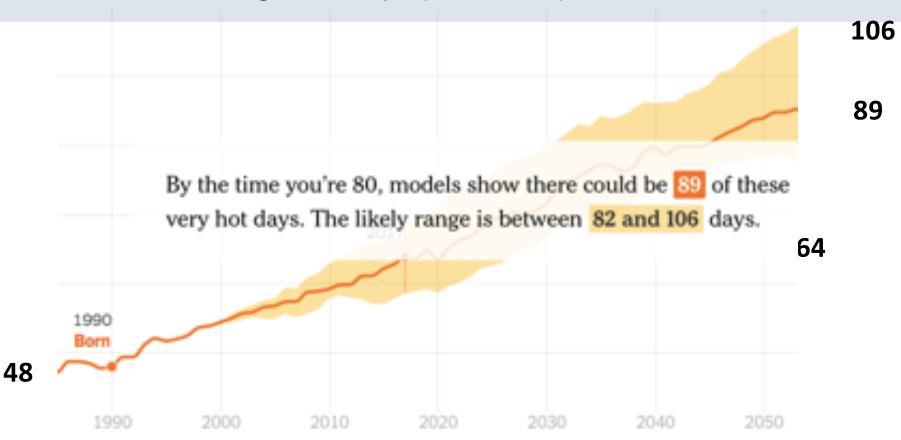# New elevation data triple estimates of global vulnerability to sea-level rise and coastal flooding

Scott A. Kulp ✉ & Benjamin H. Strauss

…PLUS OTHER
TRUSTED SOURCES

Average Hot Days (Over 32°C) in Sacramento

106

89

By the time you're 80, models show there could be [89] of these very hot days. The likely range is between **82 and 106** days.

64

1990
Born

2017

48

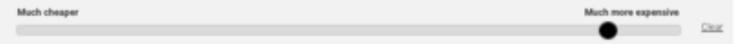1990   2000   2010   2020   2030   2040   2050

EXPERT ELLICITATION

Instructions for completing the survey:
In each of the questions below, move the ball to the point that best reflects your view on the subject of the question.

① Studies indicate that by 2050 temperatures are expected to rise by approximately 4 degrees F. What do you predict the temperature change to be?

Much lower than expected	Much higher than expected

Clear

② By 2050, the cost of renewable energy (without subsidies) compared to the cost of conventional resources will be...

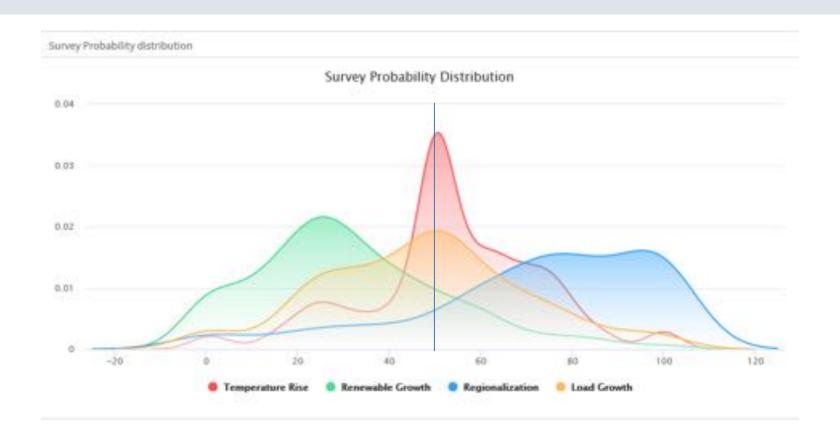| Much cheaper	Much more expensive

Clear

③ By 2050, it is expected that regional collaboration across the West could evolve from the existing Energy Imbalance Market to an expanded participation in the Day-Ahead Market to full participation options with a single ISO/RTO in the West. What level of regional collaboration do you expect?

No change (status quo)	Full RTO participation across the West

Clear

④ By 2050, annual demand is expected to increase by approximately 60% compared to our current demand levels. What do you expect the demand growth to be?

Much less than expected	Much more than expected

Clear

EXPERT FORWARD SENTIMENT

Ice sheet contributions to future sea-level rise from structured expert judgment

Jonathan L. Bamber, Michael Oppenheimer, Robert E. Kopp, Willy P. Aspinall, and Roger M. Cooke

WHAT IS MISSING?

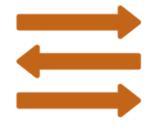# CLIMATE-RELATED DATA IS FRACTURED…

Housed in many sites, multiple domains

In many languages
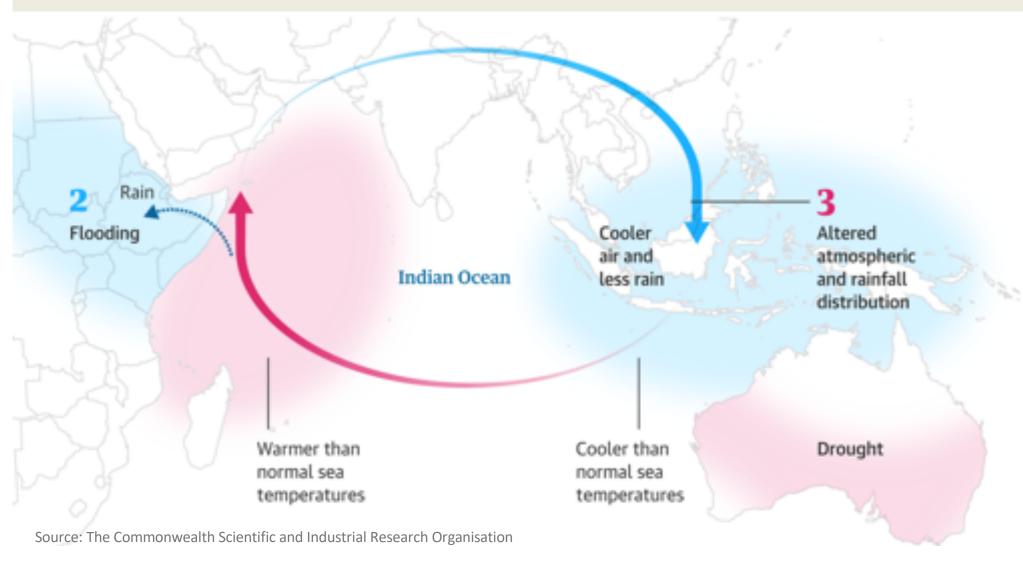
Of inconsistent quality

Using mixed models and measures

Not readily available

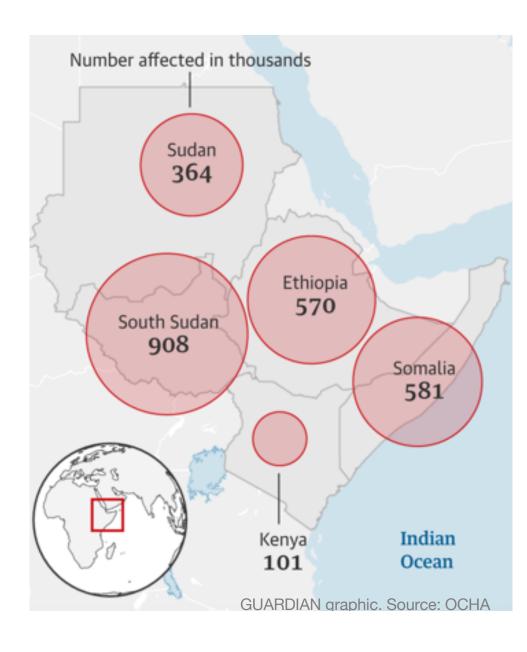# MACRO RISK FACTORS
TO LOCAL RISK FACTORS?

CLIMATE SCIENCE
IS COMPLEX

we cannot understand how macro factors
influence local factors without scientific input

THE INDIAN OCEAN DIPOLE WORSENS AS GLOBAL TEMERATURE RISES

2 Rain
Flooding

3
Altered atmospheric and rainfall distribution

Cooler air and less rain

Indian Ocean

Warmer than normal sea temperatures

Cooler than normal sea temperatures

Drought

Source: The Commonwealth Scientific and Industrial Research Organisation

Flooding has affected more than **2.5 million** people in Eastern Africa from July – Nov. 2019

Number affected in thousands

Sudan
364

Ethiopia
570

South Sudan
908

Somalia
581

Kenya
101

Indian Ocean

GUARDIAN graphic. Source: OCHA
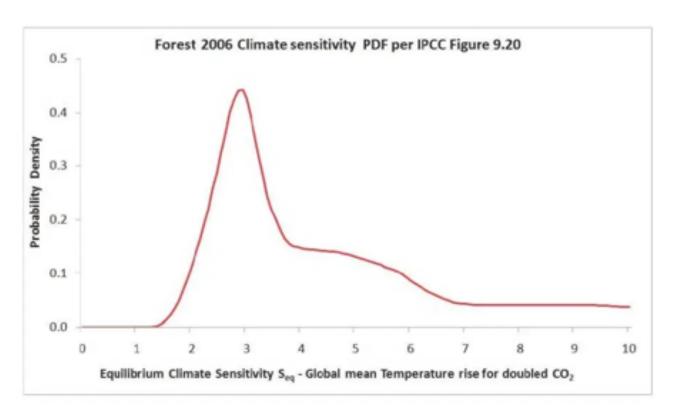
AUSTRALIA BURNS (NOVEMBER 2019)

CLIMATE CHANGE IS A FAT-TAILED PROBLEM

FIGURE SOURCE: IPCC AR4 WG1 report
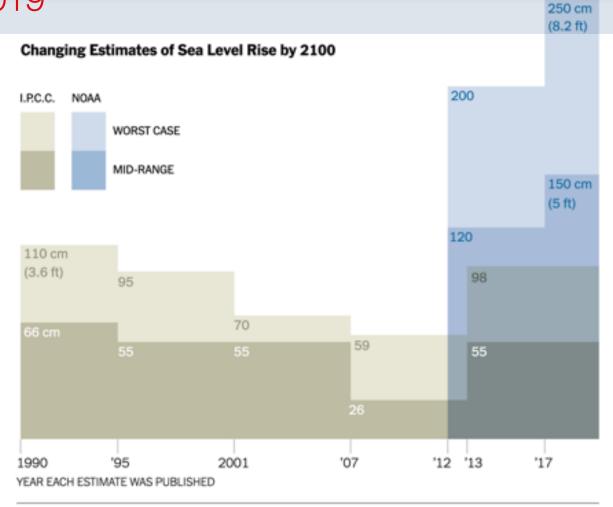
How Scientists Got Climate Change So Wrong

Few thought it would arrive so quickly. Now we're facing consequences once viewed as fringe scenarios.

By Eugene Linden
Mr. Linden has written widely about climate change.

Changing Estimates of Sea Level Rise by 2100

I.P.C.C.   NOAA

WORST CASE

MID-RANGE

250 cm (8.2 ft)

200

150 cm (5 ft)

120

110 cm (3.6 ft)

95

98

70

66 cm

59

55

55   55   55

26

1990   '95   2001   '07   '12 '13   '17

YEAR EACH ESTIMATE WAS PUBLISHED

Note: The I.P.C.C.'s 2007 estimate of future sea level rise did not include satellite data on the contribution of melt water from Greenland and Antarctica because of disagreements among scientists.
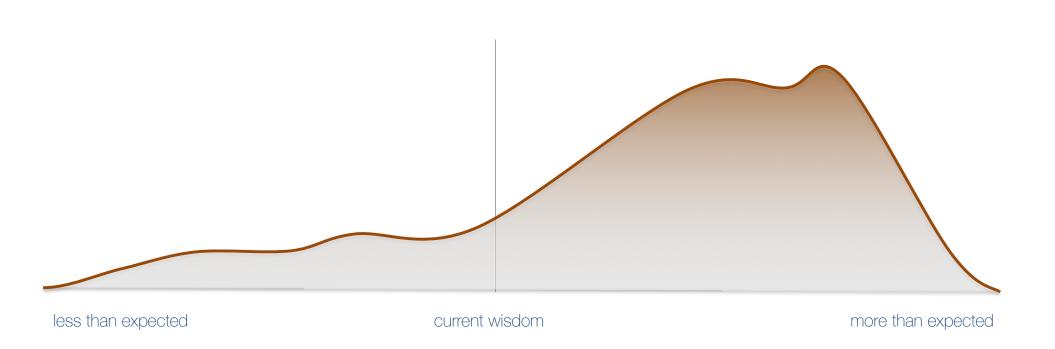
A HERETIC IN 1975; A HERO IN 2019

…..the exponential rise in the
atmospheric carbon dioxide content
will tend to become a significant
factor and by early in the next century
will have driven the mean planetary
temperature beyond the limits
experienced during the last 1000
years.

Wallace S. Broecker
AAAS Journal; 1975

NECESSARY CONDITIONS FOR "GOOD" SCENARIOS

1. Standardized methodologies to achieve consistency

2. Mixed and multi-factors

3. Evidence-based

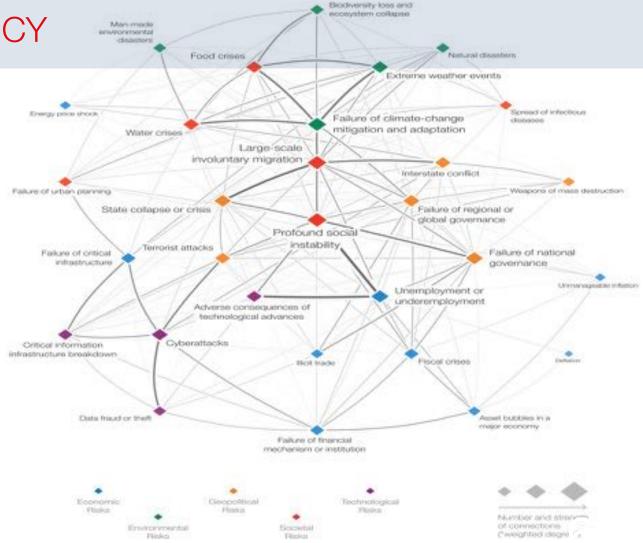4. Mathematically sound

5. A "spanning set"

6. Explainable
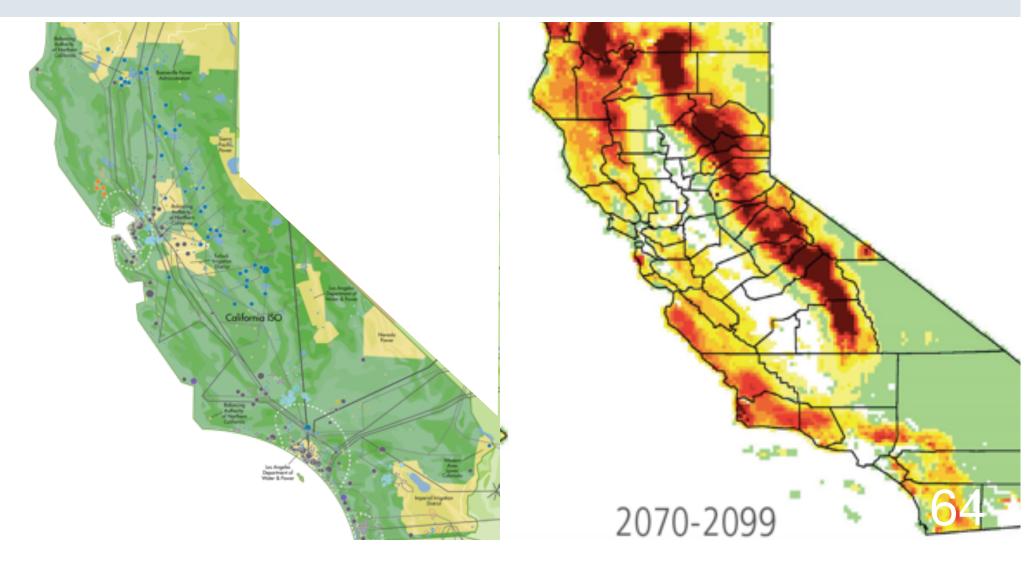
THE PEER-REVIEWED VIEW OF A RISK FACTOR AT A GIVEN HORIZON

less than expected — current wisdom — more than expected

FACTOR DEPENDENCY

NETWORK OF CLIMATE FACTORS AND THEIR INFLUENCE ON ONE ANOTHER

Source: Oliver Wyman

2070-2099

64

SUMMARY: DEVELOPING STRATEGY USING SCENARIOS

1. Select a horizon;

2. Identify the appropriate risk factors;

3. Generate the forward distributions for each factor at the horizon;

4. Calibrate the distributions with the best available science;

5. Develop the scenarios on multiple factors from the single factor scenarios;

6. Value the entity under each scenario;

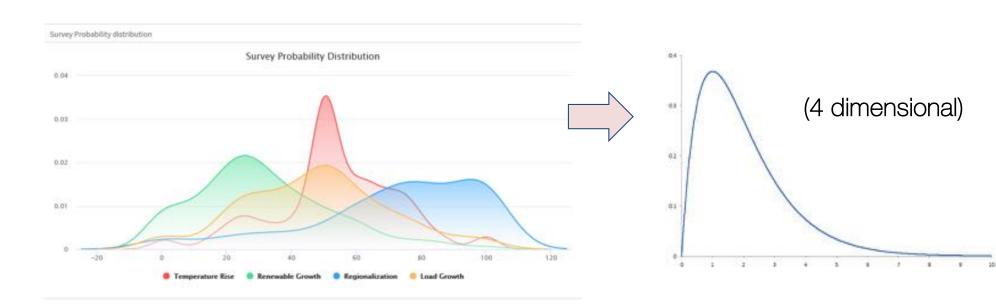7. Prune the tree (know your bets).

MANAGEMENT ←→ BOARD RISK THINKING

1. Identify the very best opportunities and worst-case scenarios

2. Decide which (if any) scenarios to ignore (= your bets)

3. Hedge the "Black Swans"

4. Orient the strategy to the opportunities

5. Present all scenarios to the Board – discuss your bets

IMPLEMENT A "BASEL 5" FOR CLIMATE RISK!

Given $D_1(f_1)$; $D_2(f_2)$; $D_3(f_3)$; $D_4(f_4)$ derive $D(f_1, f_2, f_3, f_4)$

(4 dimensional)

THANKS FOR YOUR ATTENTION

CONTACT:

Ron Dembo

rdembo@riskthinking.AI